

GRAVITY BASE STATIONS IN SOUTH DAKOTA

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ABSTRACT

Thirty-two gravity base stations of record are described for South Dakota. A station of record is defined as: having an accuracy of at least 0.1 mgal., being on file as a base station in the United States Geological Survey's gravity database, having a field location readily discernible to within 1/2 foot, and preferably marked.

During field work for the new South Dakota Bouguer Anomaly Map, a check of existing base stations was conducted. Several new base stations were measured and monumented; some older stations were excluded because of site destruction or accuracy requirements. A network of base stations at intervals of approximately 50 miles has been established throughout the state. Station spacing is greater in the northwest.

Each station's name (town), latitude, longitude, elevation, and observed gravity is listed. Brief, specific local directions are given to each site. These base stations comprise a fundamental gravity reference for the state.

INTRODUCTION

The most accurate gravity surveys are land based and involve measuring "g", the acceleration due to gravity at ground level (Robinson and Coruh, 1988). The instrument used is the gravity meter, a sensitive balance in which small changes in g exert torques on a mass of fixed size. As learned in basic physics, g for the earth at sea level averages about 980 cm/sec/sec. These units are termed "gals", after Galileo. Units of one thousandth of a gal, the milligal, are commonly used. Thus g for earth averages about 980,000 mgal. at sea level.

Gravity meter readings are relative; that is, the given meter reading is the amount of change from a location where observed gravity is accurately known. These reference locations can be divided into two general types, primary and base. At primary stations, the total value of g was determined. This is a painstaking and cumbersome measurement commonly using either a pendulum or falling weight. Accuracies of .04 to .06 mgal. are typical (Hammond and Faller, 1971). The more common base stations have their values determined relatively, by measuring the difference from a known reference (primary or another base). A gravity meter is used; this is a fast and simple measurement. Gravity meters, such as the LaCoste and Romberg instrument, are capable of measuring gravity variations as small as 0.01 mgal. Thus, differences in g can be measured more accurately and quickly than the actual value of g.

In 1987 the writer began field work for the new South Dakota gravity anomaly map (Zawislak, 1989). A typical day's survey consisted of a loop of 50 mea-

surements beginning and ending at a base station. In this work it was essential to have access to a nearby base station. In early 1987, approximately 25 South Dakota base stations were on file with the United States Geological Survey (USGS) in the gravity database for the US (Kucks, 1987). Many of these were established in the late 1960's by geodetic teams of the US Air Force. This was in conjunction with widely spaced gravity survey work related to Air Force missile installations in the north central and northwestern US.

In the course of the South Dakota survey work, it was discovered that some of the base stations had been destroyed, and that some were not of sufficient accuracy (in location and/or g value). As a second project, the writer undertook a reconnaissance of all the state's gravity base stations and the establishment of new ones where needed.

CONSIDERATIONS

Some earlier base station work, particularly that of the US Air Force, has not withstood the test of time. Many of the stations were installed at airports. Unfortunately, over the past 25-30 years, commercial air travel grew rapidly. Old airports were expanded, replaced, or abandoned; base station sites were often destroyed.

Some recent work involved establishment of what will be termed "temporary" base stations (C. Magee, 1988). These were carefully measured sites, such as a point at the side of the road, that were used for several days as the reference for local gravity studies, then abandoned and never monumented. It soon became apparent to the writer that the concept of a gravity base station needed to be carefully defined before a list could be drawn up.

For the purposes of this report, only gravity base stations of record are listed. Stations of record:

1. have gravity measured to at least 0.1 mgal. accuracy;
2. are on file as a base in the USGS's gravity database;
3. have a field location identifiable to within 1/2 foot (horizontally and vertically);
4. are monumented (preferably) — usually as a gravity base, or, sometimes an existing bench mark is used.

The 1/2 foot location requirement is of particular importance in the vertical. Gravity changes as the inverse square of distance from earth's center. A one foot change in elevation amounts to a 0.1 mgal. change in gravity (Robinson and Coruh, 1988). Practically, if the station's exact site is not marked (or at least measured with respect to some nearby object), it is seldom possible to relocate within 1/2 foot.

PROCEDURE FOR NEW BASES

Gravity surveys in large areas of the state with no nearby bases led the writer to conclude that a base station spacing of about 50 miles was most expeditious. A close base is convenient. It saves time by reducing the survey team's travel. On the other hand, it takes time, about one day, to set up each monumented base.

New base stations were installed at towns with restaurants, lodging, and access to major roads, in other words, in locations from which future gravity surveys could be conveniently centered. Readily accessible landmark buildings, not likely to be torn down, were the first choice. The county courthouse (steps, porch, foyer, etc.)

being a common location, the station should be as “permanent” as reasonably possible. The following steps were involved.

- Field:**
1. Select location, obtain permission to place station.
 2. Carefully measure gravity at an existing base station.
 3. Drive to the new location, carefully measure gravity.
 4. Drive back to existing base station, carefully measure gravity.
 5. Repeat steps 3 and 4 until 2 to 4 measurements are obtained for the new station.
 6. Affix (bolt and epoxy glue) the marker plate at the new site.
- Office:**
1. Reduce data: correct for earth tides, minor instrument drift, etc.—a standard procedure (Dobrin and Savit, 1988).
 2. Prepare (draft) a locator sheet with: area map, directions to the new station, observed gravity, latitude and longitude, elevation, etc.—a standard USGS format.
 3. Send results to USGS for incorporation into the national gravity database.

RESULTS

There are presently 32 gravity base stations of record in South Dakota. Figure 1 shows their statewide location. Station spacing averages about 50 miles throughout most of South Dakota. However, in the northwest, spacing is greater. Table 1 lists the following basic data for each station: name, elevation, latitude, longitude, observed gravity. Table 2 gives specific local directions to each of the stations. Table 3 lists 18 South Dakota gravity base stations that are on file with the USGS but do not meet the criteria defined above. These stations were excluded.

The directions in Table 2 should enable the reader to find the station’s marker plate, where present; or at least the spot, if no longer monumented. In the event the site cannot be found, a copy of the locator sheets is available, at cost, from the writer or from the geophysical branch of the Denver USGS.

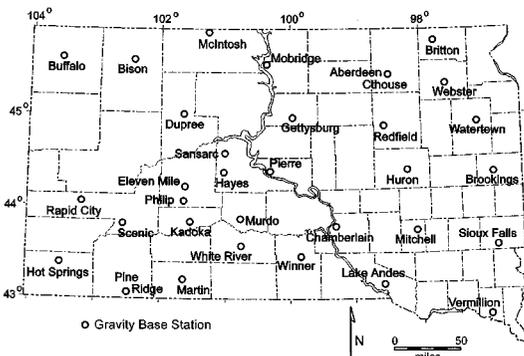


Figure 1. Distribution of Gravity Base Stations.

Table 1. South Dakota Gravity Base Station Data.

No.	Station	Elev. (ft.)	Latitude (N) (deg., min.)	Longitude (W) (deg., min.)	Obs. Gravity* (mgals)
1	Aberdeen Cthouse	1303	45 27.87	98 29.17	980531.28
2	Bison	2782	45 30.90	102 28.35	980423.35
3	Britton	1366	45 47.45	97 45.24	980550.60
4	Brookings	1638	44 19.02	96 46.93	980414.33
5	Buffalo	2876	45 35.00	103 33.00	980431.34
6	Chamberlain	1720	43 47.40	99 19.20	980327.55
7	Dupree	2380	45 2.85	101 36.08	980396.54
8	Eleven Mile	2395	44 11.81	101 39.99	980311.22
9	Gettysburg	2161	45 0.68	99 57.23	980436.81
10	Hayes	2050	44 22.37	101 2.02	980349.08
11	Hot Springs	3460	43 25.89	103 28.50	980173.13
12	Huron	1283	44 23.00	98 33.30	980438.59
13	Kadoka	2460	43 49.95	101 30.60	980266.59
14	Lake Andes	1480	43 9.16	98 32.52	980280.69
15	Martin	3330	43 10.50	100 44.10	980160.61
16	McIntosh	2301	45 55.27	101 21.00	980497.73
17	Mitchell	1290	43 46.12	98 2.39	980367.33
18	Mobridge	1715	45 33.00	100 24.00	980511.73
19	Murdo	2326	43 53.38	100 42.78	980264.63
20	Philip	2162	44 2.33	101 39.97	980313.38
21	Pierre	1719	44 22.85	100 17.02	980405.08
22	Pine Ridge	3235	43 1.45	102 33.75	980144.54
23	Rapid City	3202	44 4.90	103 12.90	980257.16
24	Redfield	1303	44 52.61	98 31.00	980496.00
25	Sansarc	2080	44 31.89	101 2.02	980378.35
26	Scenic	2809	43 46.73	102 33.07	980261.86
27	Sioux Falls	1450	43 34.20	96 44.00	980345.21
28	Vermillion	1234	42 47.05	96 55.72	980309.54
29	Watertown	1731	44 53.91	97 6.85	980452.12
30	Webster	1857	45 19.95	97 31.29	980482.25
31	White River	2067	43 34.05	100 44.70	980244.95
32	Winner	2038	43 23.40	99 50.55	980239.31

* Referenced to IGSN 1971 Datum.

Table 2. Local Directions to Gravity Base Stations.

- 1 **Aberdeen Cthouse** — at the (new) south entrance to the Brown Co. Courthouse in Aberdeen; on the east side of a covered entry, about 3 feet in front of the doors; monumented with a USGS aluminum gravity base plate.
- 2 **Bison** — at the Perkins County Airport, near Bison; on the concrete at the east edge of the south door of a white wooden hanger between older hangers; marker plate absent but some glue remains, location obvious.
- 3 **Britton** — at the north (Hwy 10) side of the Marshall Co. Courthouse in Britton; at the southwest corner of an outside landing; monumented with a USGS aluminum gravity base plate.
- 4 **Brookings** — on the South Dakota State Univ. campus in Brookings; on a concrete pad at the southwest corner of the Student Union Building; beside a bench mark and electric box; monumented with a USGS aluminum gravity base plate.
- 5 **Buffalo** — in north Buffalo, west of US Route 85, on the grounds of Buffalo High School; in the southeast corner of a 6 feet high woven wire fence; at the monumented bench mark stamped "B32 1934".
- 6 **Chamberlain** — at the airport, south of Chamberlain; at the southeast corner of the most westerly hanger; on the concrete building footing; monumented with a USAF gravity disk.
- 7 **Dupree** — at the Ziebach Co. Courthouse in Dupree, 25 feet from the main (west) entrance; 1 foot north of a flagpole and 1 foot lower in elevation than a nearby bench mark; monumented with a USAF gravity disk.
- 8 **Eleven Mile** — 10 miles north of Philip (Hwy 73) at "eleven-mile" intersection; on the southeast side of the intersection at existing bench mark K371 1962.
- 9 **Gettysburg** — at the Potter Co. Courthouse in Gettysburg; outside, at the south end of the top step to the west entrance; marker plate absent, location obvious.
- 10 **Hayes** — near the T5N, R25E, S24/25 and T5N, R26E, S19/30 corner; on the northeast side of a short curving road segment that bypasses this corner; at a bench mark labeled "Hayes 1952".
- 11 **Hot Springs** — at the Post Office in Hot Springs; on the front (south) porch landing, 3 feet west of the entrance doors; marker plate absent, location obvious.
- 12 **Huron** — one mile north of Huron, at the airport; on a concrete step to the east door of a stone and mortar hangar; marked with a bronze disk stamped "USC&GS Gravity Station".
- 13 **Kadoka** — inside the Post Office in Kadoka; on the tile floor at the window between the two northeast corner entrances; monumented with a USAF gravity disk.
- 14 **Lake Andes** — south of Lake Andes, at a gas station on Hwys 281 and 18, and 0.25 miles west of the junction with Hwy 50; at the west corner of the station building, on the concrete sidewalk; marker plate absent, location obvious.
- 15 **Martin** — inside the Post Office at Martin; in the mailbox room, at the north-west corner, 8 feet north of the entrance; marker plate absent, location obvious.
- 16 **McIntosh** — at the Corson Co. Courthouse in McIntosh; on the northwest corner of the concrete base of the south steps leading to the porch at the main entrance; marker plate absent, location obvious.
- 17 **Mitchell** — at the Municipal Airport north of Mitchell; on the field side of the wooden frame hanger, at the northeast corner of the sliding door casing, on the concrete floor; remonumented with a USGS aluminum gravity base plate.

- 18 **Mobridge** — at the Mobridge Airport, at a hanger 200 yards east of the National Guard Armory; beside a power pole next to a phone booth at the northwest corner; monumented with a USAF gravity disk.
- 19 **Murdo** — in Murdo, on the sidewalk directly in front of the corner stone of the First Fidelity Bank on Main Street; the corner stone is monumented as “USC&GS BM E9 1925”.
- 20 **Philip** — at the Haakon County Courthouse in Philip; on the north side of the tiled top step to the S. Howard St. entrance; at the monumented site “USC&GS BM J-22 1933”.
- 21 **Pierre** — at the Pierre Municipal airport; on the field side of the terminal, at the east corner of the building on the concrete apron, 50 feet from the lobby entrance; marker plate absent, location obvious.
- 22 **Pine Ridge** — in Pine Ridge, at the Sioux Indian Agency complex; in the center of the north sidewalk of Main Street; approximately 100 feet west of the Red Cloud Center, and just southwest of the Oglala Tribal Office; monumented with a brass disk inscribed “Bureau of Indian Affairs ‘A’”.
- 23 **Rapid City** — at Community Care Center, Inc. (formerly the Municipal Building, main entrance to west) in Rapid City; inside and 2 feet east of the doors, in the corner of the tile floor; monumented with a US National Gravity Base disk.
- 24 **Redfield** — outside the Redfield Post Office; on the concrete landing at the top step of the main (north) entrance, and just to the west of the doors; marker plate absent but some glue remains, location obvious.
- 25 **Sansarc** — at the corner of T7N, R25E, S25/36 and T7N, R26E, S30/31; 10.8 miles north of Hayes at the northwest corner (roadside) of an intersection of gravel roads; monumented as bench mark “MC67” (reset 1977).
- 26 **Scenic** — in southern Scenic, near Hwy 40, at the school; in the northeast corner of the landing at the top of the stairway to the main entrance; marker plate absent but some glue remains, location obvious.
- 27 **Sioux Falls** — inside the Post Office, in the Federal Building at S 2nd and E 12th Streets; on the terrazzo floor, in the southwest corner (formed by entrance vestibule and outside wall) of the mailbox room; monumented with a National Gravity Base disk.
- 28 **Vermillion** — on the University of South Dakota campus in Vermillion; outside the main (Dakota Street) entrance to Akeley Science Center; on a covered concrete walk, against the building wall and just north of the entry doors; monumented with a USGS aluminum gravity base plate.
- 29 **Watertown** — outside the back (2nd Ave S) entrance to the Codington Co. Courthouse; on a landing, and 3 feet to the east of the entry doors; monumented with a USGS aluminum gravity base plate.
- 30 **Webster** — outside the east entrance to the Day Co. Courthouse; on the granite floor of a covered porch, against the wall and 8 feet north of the entry doors; monumented with a USGS aluminum gravity base plate.
- 31 **White River** — inside the White River Post Office; on the floor at the south side of an enlarged mailbox room; monumented with a USAF gravity disk.
- 32 **Winner** — one mile north of Winner, at the airport; on the concrete ramp about 10 feet north of the northeast corner of the maintenance shop, and beside a concrete pad that once had a gas pump; monumented with a USAF gravity disk.

Table 3. USGS On-file Base Stations Not Meeting Criteria.

Station & Location (County)	Reason Excluded
Aberdeen (old), Brown Co. Spearfish, Lawrence Co.	destroyed — new construction
Bowdle, Edmunds Co.	moved (by tornado)
Egan, Moody Co. Herreir, Campbell Co. Junction City, Clay-Union Co. line	0.3 mgal. accuracy
Highmore (old), Hyde Co.	not found (destroyed?)
Highmore* (new – airport), Hyde Co. near base of phone pole (abandoned, location within 1 to 4 ft.?)	never monumented,
Lees Corner*, Buffalo Co. Midland*, Haakon Co. Miller*, Hand Co. Standing Butte Ranch*, Stanley Co. Stony Butte*, Lyman Co.	never monumented, a spot beside or in road (location within 2 to 5 ft.?)
BA2.1423*, Stanley Co.	location uncertain (at a bench mark?),
BA2.1326*, Hughes Co. BA2.1651*, Jerauld Co. BA2.1718*, Hand Co. BA2.2300*, Hughes Co.	never monumented, a spot beside or in road (location within 2 to 5 ft.?)

* These 1987 EDCON bases were carefully measured and may be useable if exact site can be relocated.

ACKNOWLEDGMENTS

Initial funding for the first year of reconnaissance was provided by the University of South Dakota. The United States Geological Survey (W. Pratt, T. Hildenbrand, W. Day) and the South Dakota Geological Survey (L. Hedges, M. Tipton, C. Christensen) funded surveys for the new state gravity map, which is nearing completion. Base station work was a necessary part of this project. John Ahart assisted in checks of existing stations and in installation of new bases. C. Magee (EDCON) provided data on base stations added in late 1987. Robert Kucks (Denver USGS) helped with data reduction. Julia Heaton reviewed the data.

REFERENCES CITED

- Dobrin, M.B., and C.H. Savit. 1988. *Introduction to Geophysical Prospecting*. McGraw-Hill Book Company, New York.
- Hammond, J.A., and J.E. Faller. 1971. Results of absolute gravity determinations at a number of different sites. *J. of Geophys. Research*. 76:32:7852.
- Kucks, R. 1987. *Personal communication*. Geophysical Branch, U. S. Geol. Survey, Denver.
- Magee, C. 1988. *Personal communication*. Exploration Data Consultants, Inc. (ED-CON), Denver.
- Robinson, E.S., and C. Coruth. 1988. *Basic Exploration Geophysics*. John Wiley and Sons, New York.
- Zawislak, R.L. 1989. The status of detailed gravity mapping in South Dakota. *Proc. S.D. Acad. Sci.* 68:101-105.